Oct. 9, 1962 M. A. MALLINGER 3,057,405

METHOD FOR SETTING WELL CONDUIT WITH
PASSAGES THROUGH CONDUIT WALL

Filed Sept. 3, 1959

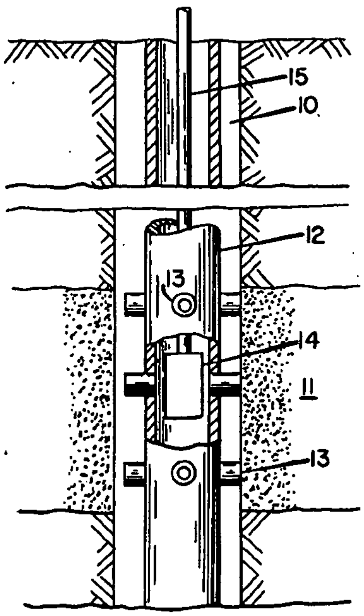

FIG. 1

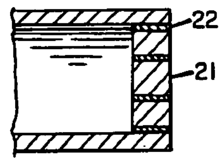

FIG. 3

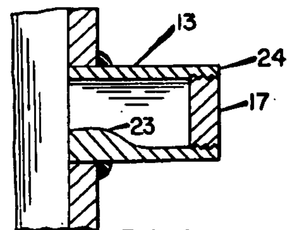

FIG. 4

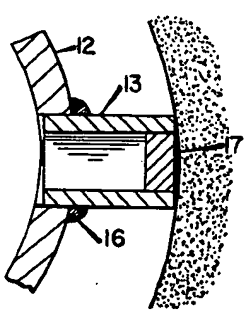

FIG. 2

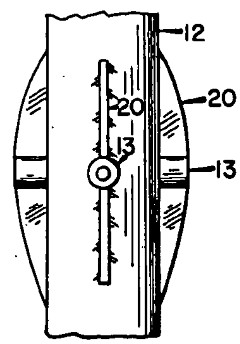

FIG. 5

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METHOD FOR SETTING WELL CONDUIT WITH PASSAGES THROUGH CONDUIT WALL

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This invention relates to completing wells. More particularly, it relates to placing a conduit in a well and forming openings through the wall of said conduit through which fluids can flow into the conduit.

In the drilling of wells for the production of oil or gas, a conventional procedure is to drill through the prospective producing formation and then run a string of metallic casing into the well and through the formation. The casing is then cemented in the conventional manner to seal off the prospective producing formation from underlying or overlying formations containing water or gas. Thereafter, the metal casing is perforated by means of bullets or shaped explosive charges. These pierce the pipe and cement sheath and penetrate into the surrounding earth formations to provide channels through which oil and gas can enter the casing.

Such methods have been very successful. They are, however, quite expensive. In addition, the holes through the casing are generally small. They provide little flow capacity for liquids flowing from the formation into the well. The restriction is particularly serious when fluids are forced out through the holes at high rates in order to fracture the surrounding formation.

Efforts to overcome such difficulties have included the use of weakened sections of the casing which can be ruptured by the fracturing fluid. Such a system is described in U.S. Patent 2,642,142 issued on July 16, 1953, to J. B. Clark. Other efforts have included the use of sections of casing which can be removed by solvents such as acids. Alloys sold under trademarks such as Securaloy are available for this purpose. Still other attempts to overcome the difficulties of gun perforating have included placing explosive charges in projections extending through and outside the casing wall. The explosives, when detonated, form large passages through the casing and projections. An example of this type of development is found in U.S. Patent 2,201,290 issued on May 21, 1940, to H. M. Greene.

All these schemes have their difficulties. For example, if a weakened section of the casing is strongly supported by cement, it may be as difficult to burst as an unweakened section of casing not supported by cement. There is sometimes danger therefore of bursting the casing at the wrong level.

The use of solvents may also be successful. Once a small hole forms in the soluble section, however, the remaining solvent may leak away through the hole to the formations surrounding the section. In this case, the first small hole is all that is formed. If the pressure outside the casing is greater than that inside, fluids from the outside enter the first small hole diluting the solvent and driving it away from the section to be dissolved. Again, only a single small hole may result. In addition, solvents such as acids have at least some solvent action on the steel casing as well as on the special section to be dissolved. The use of expensive operating procedures to dissolve the casing section are also required, as in the case of the gun perforator.

The use of small charges of explosives placed in the casing wall to blow holes in the casing should be successful in some cases. As noted in the Greene patent referred to above, however, explosives are thermally sensitive. Placing such explosives in deep wells may result

in premature detonation of the explosive by the high temperatures of such wells before the casing can be cemented in place. Many explosives are not operable under high pressures in wells. There may be some difficulty from this standpoint. The principal difficulty however is that the outer side of the chamber which holds the explosive is supported by the formation or the cement outside the casing. The inner wall is not supported. Therefore, as often as not, detonation of the explosive removes the inner wall without bursting the strongly supported outer wall.

With the above problems in mind, an object of this invention is to provide a means for completing a well in which a large passage is formed through the wall of a conduit lowered into the well. Another object is to provide a means for forming a passage through the casing lowered into the well which means does not require the use of expensive special apparatus or manipulations. Still another object is to provide apparatus specially adapted for simple inexpensive well completion operations in which a passage through a well conduit wall is required. Other objects will be apparent to those skilled in the art from the following description and claims.

My method of completing wells can best be illustrated in connection with a casing cementing operation. In this case, a section of casing is provided which has projections sticking out of it. A passage is provided through the casing wall and through the projections. The outer end of the passage is plugged by a material which can be melted in any of several ways. The casing is run into the well, with the special section inserted at the proper point to be set opposite a producing zone of the well. After the casing is lowered into the well, it is cemented in place. The plug is then melted out of the end of the passage to form an opening extending from the formation to the interior of the casing.

My invention will be better understood by reference to the drawing in which:

FIGURE 1 is a cross-sectional view of a well showing an embodiment of my invention in which a section of casing has projections containing passages plugged at their outer ends with a material which can be melted to open the passages.

FIGURE 2 is a detailed view in cross-section of one form of a projection with a plug in its outer end.

FIGURE 3 is another detailed view in cross-section showing a form of projection in which the plug in the outer end is reinforced to prevent premature collapse.

FIGURE 4 is a cross-sectional view of another form of projection in which a reservoir is provided for the molten plug so this material will not enter the well.

FIGURE 5 is a view of a section of casing in which the projections are supported by webs extending along the casing.

In FIGURE 1, a well **10** penetrates an oil producing sand **11**. A string of casing **12** has been lowered into the well. This casing includes a section having projections **13** extending outwardly. The section bearing the projections is set opposite the producing formation. An electric heater **14** is shown lowered into the casing on electric cable **15**.

The character of the projections can be seen in more detail in FIGURE 2. Here, the projection **13** is a tube extending through casing **12**. The tube is attached to the casing by means such as weld **16**. The tube is closed at its outer end by a plug **17**. The plug is formed from a low-melting alloy.

In using the apparatus shown in FIGURES 1 and 2, the casing is lowered into the well until the special section is opposite the producing formation. The casing is then cemented in place by running a string of tubing into the well with a packer on the bottom, setting the packer be-

tween the casing and tubing near the bottom of the casing string, and pumping Portland cement slurry down the tubing and up around the outside of the casing. After the cement is set, the tubing is withdrawn and the heater is lowered through the section opposite the producing formation to melt the alloy plugs at the ends of the tubes and permit flow of formation fluids into the casing from which it can be removed to the surface of the earth by pumps or other well-known means.

The alloy should have a low melting point. If the casing is heated to a temperature very much above about 700° F., the cement behind the casing may be seriously damaged. The critical temperature of water is about 700° F. Temperatures above this value may seriously interfere with hydration of the cement as well as adversely affecting the bond between the cement and the casing. For these reasons, the plugs in the passages through the casing and projections should have a melting point which is not above about 700° F. Preferably, the melting point should be no more than about 100° F. above the normal static temperature of the formation opposite which the special section of casing is to be set. This is to decrease the amount of heat which must be generated to melt the plugs.

The trouble of running a tubing string for the cementing job can be avoided by pumping cement down the casing itself. In this case, however, the passages through the casing and projections should be either completely filled with the low-melting alloy or at least the passages should be plugged at both the outer and inner ends.

While the above-described method represents one embodiment of my invention, it is not the preferred or most advantageous form. The use of the heater is certain and convenient, unlike some of the techniques with explosives and solvents. Nevertheless, it does involve the extra step of lowering the heater into the well. This step can be avoided in two ways. In shallow wells, water or other liquid can be circulated in the well before the casing is run. Experience has shown that the bottom hole temperature can be lowered about 40° F. by circulating a liquid such as drilling fluid in the well. About eight hours are then required for the temperature to rise to the normal static bottom hole value. This makes possible a process with certain advantages. In this process, a cool liquid is first circulated in a well to decrease the bottom hole temperature by about 40° F. The liquid temperature must be at least about 50° F. below the normal static bottom hole temperature for this purpose. The circulation is made through a string of tubing or drill pipe in the well. After several hours of circulating, preferably at least about eight hours, the tubing or drill pipe is withdrawn and the casing string is immediately run into the well. The special section of the casing, which includes the plugged passages, is set opposite the producing formation as before. Again, Portland cement is placed outside the casing. In this case, however, the plugging material in the ends of the passages has been selected with unusual care.

The melting point of the material lies somewhere between about 20° F. below the normal static bottom hole temperature and about 20° F. above the normal static bottom hole temperature.

The bottom of the well slowly warms to normal static bottom hole temperature. In addition, the cement generates considerable heat while setting. The combination of the two heat sources raises the casing temperature to a value of at least about 20° F. above normal static bottom hole temperature, about eight hours after the cement is introduced. This is sufficient to melt the plugs in the passages through the casing. It will be noted that in this process, openings of any desired size are formed through the casing wall with no manipulative steps, with one exception, beyond those normally used in a cementing operation. This exception is the initial simple circulating step.

The melting point of the plugging material should be no lower than 20° F. below the normal static formation temperature event though the well temperature is lowered to 40° F. below the normal static value by circulation. This is to allow a factor of safety. The well begins warming up during the withdrawal of the circulation conduit and the running of the casing into the well. If any delay is encountered after the casing is in place in the well but before the cementing operation begins, the well can be kept cool by slowly circulating a cool liquid through the casing. As soon as circulation of the cement slurry is initiated, this slurry cools the well and prevents premature melting of the plugs in the passages.

Even the circulating step can be avoided in the preferred embodiment of my invention. In this case, the material used to plug the passages through the casing wall is even more carefully selected. It has a melting point slightly above the normal static temperature of the producing formation opposite which the special section of casing is to be set. The melting point of the plug should be between the normal static temperature of the producing formation and a temperature about 20° F. above this normal static temperature. Since the melting point is above the normal static temperature, no cooling of the well is required before the casing is lowered into place. The plugging material is melted solely by the heat generated by the cement in setting. Again to allow a safety factor, the melting point should usually be at least about 5° F. above the normal static formation temperature.

In this preferred embodiment, the projections on the outside of the casing become very important. FIGURE 1 of the drawing shows the projections on one side of the casing lying against the well wall. This is the usual case. A well is almost never absolutely vertical. Therefore, the casing almost always lies against the well wall on one side. In the absence of the projections, the casing itself would be against one wall. On this side, little, if any, cement could exist between the casing and the well wall. Therefore, little heat could be generated and the plugs and the passages on that side might not melt. With projections extending outwardly at least about an inch from the casing wall, however, adequate cement is provided to raise the casing temperature at least about 20° F. or more above the normal static formation temperature.

Centralizers could, of course, be used to hold the casing away from the well wall as in ordinary cementing practices. In the case of my invention, however, it is preferred that centralizers other than the projections should not be used. In this connection the other important purpose of the projection is to be noted. In holding the casing away from the well wall, the projection itself is pressed against the well wall. Therefore, when the plug is melted from the passage, a clear opening is provided on at least one side of the casing from the interior of the casing through the cement to the formation. If centralizers other than the projections are used, there is some chance that at least a thin film of relatively impermeable cement may be outside all the passages. A hydraulic fracturing operation, which preferably follows my method, will generally burst through any cement films, but fracturing is much simpler if the permeable formation itself is exposed to the end of the passage.

If the projections are to be used as centralizers, it will be apparent that they will drag along the well wall. To decrease the danger of knocking off some of the projections, they should be reinforced as shown in FIGURE 5. In this figure the projections 13 on casing 12 are supported by webs 20 extending along the casing.

Many different types of materials may be used to plug the passages through the casing wall. Some inorganic solids have melting points in the desired range. These include the hydrated nitrates such as those of chromium, iron, mercury, and nickel. Most of the low-melting in-

organic salts are too water soluble for general use however.

Crude organic materials, such as paraffin, gilsonite, beeswax and the like, may be used if one can be found which has the required strength and the close melting range at the desired temperature for a particular well. If organic materials are used however, it is preferred that relatively pure compounds be employed. Table 1 presents a list of pure compounds having sharp melting points. Most of these materials are readily available. Their melting points are distributed throughout the range from about 100° F. to about 300° F. which is of most interest in casing oil wells.

Table 1

Material:	M.P., ° F.
Phenol	108
Paratoluidine	113
Cetyl mercaptan	122
Paradichlorobenzene	127
Orthophenylphenol	136
Palmitic acid	144
Stearic acid	156
Biphenyl	158
Glyceryl tristearate	160
Methyl beta-naphthyl ether	162
Naphthalene	176
Ethylene iodide	180
Paradibromobenzene	192
Tribenzyl amine	196
Alpha-naphthol	201
Phenoxyacetic acid	205
Phenanthrene	212
Catechol	219
Beta-naphthyl amine	234
Acetanilide	237
Benzoic acid	250
Maleic acid	266
Urea	270
Paratoluene sulfonamide	279
Parachlorobenzene sulfonamide	291
Adipic acid	306
Citric acid	307
Salicylic acid	315

Still other organic materials will occur to those skilled in the art. Many references, such as The Systematic Identification of Organic Compounds by Shriner, Fuson and Curtin, 4th edition, published by John Wiley and Sons, Inc., list large numbers of materials by their melting points, permitting selection of appropriate materials to fit almost any particular situation.

Most of the materials listed in Table 1 are crystalline solids with considerable strength. It is possible, however, that they may not withstand the pressure differences across a casing wall. This is particularly true when the casing is run with a float shoe which results in a high hydrostatic pressure outside the casing and little, if any, pressure inside. In such cases it may be advisable to taper the passages shown in FIGURE 2 so that the internal diameter of the tube 13 is smaller at the inside end opening into the casing than at the outer end extending outside the casing. Thus, if the plug tends to move inwardly from the outer end of the passage, its motion is stopped by the tapered shape of the opening.

Still another reinforcing scheme is illustrated in FIGURE 3. Here, the tube 13 has at its outer end a strong metallic plate 21 with perforations 22 plugged with the low-melting material. The reinforcing member 21 may also take the form of a multiplicity of webs or plates extending across the outer end of the passage. Still other reinforcing means will occur to those skilled in the art. It will be apparent that when reference is made to the ends of passages being closed by a material having a melting point within a certain range, this is intended to include

plugs containing reinforcing elements of materials melting above the specified range.

By far the most preferred type of material to be used as plugs for my purposes is an allow such as Wood's metal. Recently, eutectic mixtures containing indium have become commercially available. These, with the well-known eutectic mixtures of lead, bismuth, tin, and cadmium, form a series of alloys with melting points distributed throughout the desired temperature range. Table 2 summarizes some of these eutectics.

Table 2

Eutectic	M.P., ° F.	Bismuth	Lead	Tin	Cadmium	Thallium	Indium
1	117	44.7	22.6	8.3	5.3		19.1
2	136	49.0	18.7	11.3		1.2	19.8
3	137	49.5	17.6	11.6			21.3
4	138	32.7	7.5	16.7			43.1
5	141	32.5		16.5			51.0
6	155	55.6	22.2			3.6	18.6
7	158	53.3	25.8				21.9
8	158	50.0	26.7	13.3	10.1		
9	162	35.0					65.0
10	163	35.0	10.0				55.0
11	167	57.2		15.8		4.0	23.0
12	174	57.2		17.3			25.2
13	197	51.6	40.2		8.2		
14	203	52.0	32.0	16.0			
15	210	56.0				7.5	36.5
16	243			48.7			51.3
17	244			26.8		9.0	44.2
18	248		7.5	47.5			45.0
19	250		7.8	46.8		2.6	42.8
20	252				25.0		75.0
21	256	55.5	44.5				
22	281	57.0		43.0			
23	288		30.6	51.2	18.2		
24	291	60.0			40.0		

The above information is taken from handbooks and encyclopedias and does not represent original data by the inventor. Other eutectic compositions exist and will become commercially available in the future. All the above compositions have sharp melting points since they are eutectic compositions. Other alloys which are not eutectics can be used if desired as long as the range of temperatures between the all-solid and completely-liquid states is not too great. This range must be sufficiently narrow to permit adequate flow of the alloys to open the passages to flow of treating solutions from within the casing, or of formation fluids from outside the casing.

Many of the low-melting alloys are soft and weak. Therefore, it is often advisable to provide supporting perforated plates as shown in FIGURE 3. Supporting webs may also be used as described in connection with the organic plugging materials.

In FIGURE 4 of the drawing, two additional features of my invention are illustrated. Tube 13, in this case, has a raised portion 23 on the lower side of the inner end. The purpose is to prevent entry of the molten plugging material into the casing. In most cases the plugging material will have a melting point slightly higher than normal static bottom hole temperature. When this material melts due to the heat developed by setting of the cement, it ordinarily runs down the inner wall of the casing to the bottom of the well. The small amount of material usually will not interfere with subsequent well operations. This is particularly true if the plugging material is relatively soft. If a fairly strong, hard alloy is used, however, and if the melting point is near the top temperature developed by the cement, the plugging material may not have a chance to run very far down the casing before it becomes solid. If this happens, the alloy from each projection will form a bump on the inside surface of the casing. These bumps may interfere to some degree with future manipulations of well tools in the casing. If a tube, as shown in FIGURE 4, is used, however, raised portion 23 holds the molten material in the tube itself and does not permit it to flow into the casing.

As also shown in FIGURE 4, the plugging material may be threaded. This is to permit easy insertion of the

particular plugging material selected for use in a specific well. By use of such inserts, the casing section itself can be made up as a standard item. Discs of plugging material of various melting points can then be carried along to wells where the proper ones applicable to the particular well can be selected and screwed into the projections from the casing. Still other designs of replaceable plugs will occur to those skilled in the art.

To this point, my invention has been described in connection with casing cementing operations in which Portland cement is used as the cementing material. My invention is capable of several variations. For example, if the cementing material is a cold-setting plastic, no heat will be generated. The embodiments of my invention involving precirculation of the well to cool it or the use of a heater lowered into the well are still applicable.

Means other than electric heaters can also be used to melt out the plugs. For example, a mixture of magnesium and hydrochloric acid may be introduced into the well opposite the zone where heat is required. Methane and air may also be conducted to the botom of the well where they are ignited to produce the desired heat. Still other means will be apparent to those skilled in the art.

My invention even has some applications outside the field of casing cementing operation in wells. For example, it may be desired to place a slotted liner or screen in a well producing sand to exclude the sand from the pump. In such cases, the holes or slots in the liner or screen may be filled with a plugging material to facilitate washing the screen into a gravel pack, to permit circulating sand and mud from the bottom of the well, or for other purposes. Examples of such filled liners are shown in U.S. Patent 2,401,035 issued to S. M. Akeyson et al., on May 28, 1946.

In accordance with my invention, the slots of such liners or screens are filled with a material having a melting point slightly below the temperature of the formation opposite which the screen is to be set. A string of tubing is run into the well, a cool liquid is circulated in the well to lower the temperature to a point below the melting point of the plugging material. A batch of gravel is next placed in the bottom of the well. The tubing is then withdrawn, the plugged liner is placed on the bottom of the tubing and the tubing string is run into the well again. Water is circulated through the tubing and the open bottom end of the plugged screen to wash the screen into the gravel. After this operation, the well is held shut in for about eight hours to permit the well temperatures to rise to their normal static levels. The plugging materials in the slots of the screen are thus melted, opening the screen to the flow of formation fluids.

An example of the application of my invention to cementing casing in a well is as follows: The well is 5,000 feet deep and at the bottom is 9 inches in diameter. Casing 5½ inches in external diameter is to be run to the bottom. An oil producing formation is known to be present from 4,950 to 4,980 feet.

A 30-foot section of casing such as that shown in FIGURE 1 is made up. The plugs in the ends of the projections are of the replaceable type shown in FIGURE 4. These projections extend outwardly 1 inch from the outside surface of the casing. They are set 1 foot apart along the casing in four rows arranged equally around the casing. The passages through the casing and projections are 1 inch in diameter.

At the well, a recording thermometer is run to 4,980 feet. The formation temperature is found to be 150° F. Alloy number 8 in Table 2 is selected as the plugging material and discs of this material are screwed into the outer ends of the passages through the casing wall and projections to seal these passages. This alloy is the well-known Wood's metal melting at 158° F.

The casing is run into the well with the special 30-foot section 20 feet from the bottom of the string. The casing is then cemented in place with a slurry of Portland cement. The well is held shut in for eight hours to permit the cement to set and to melt out the plugs in the passages. After waiting at least 72 hours for the cement to develop a greater strength, a hydraulic fracturing operation is carried out through the open passages and the well is placed on production.

It will be apparent from the above description that my invention is capable of many variations. I do not, therefore, wish to be limited to the above specific examples but only by the following claims.

I claim:

1. A method for completing a well penetrating a producing formation comprising circulating for several hours past said formation in said well a liquid at least about 50° F. cooler than the normal static temperature of said producing formation, immediately running casing into said well, said casing including a section, set opposite said producing formation, which has a projection extending outwardly from said casing and a passage extending through said projection and the wall of said casing, the outer end of said passage being plugged by a material having a melting point in the range between a temperature about 20° F. below the normal static temperature of said producing formation and a temperature about 20° F. above the normal static temperature of said producing formation, placing Portland cement outside said casing at the level of said formation and holding said well shut in for at least about eight hours to permit the heat from the formation and from the setting of the cement to melt the plug in said passage.

2. A method for completing a well penetrating a producing formation comprising circulating for several hours past said formation in said well a liquid at least about 50° F. cooler than the normal static temperature of said producing formation, immediately running casing into said well, said casing including a section, set opposite said producing formation, which has a projection extending outwardly from said casing and a passage extending through said projection and the wall of said casing, the outer end of said passage being plugged by a material having a melting point in the range between the normal static temperature of said producing formation and a temperature about 20° F. below said normal static temperature of said producing formation, placing a cementing material outside said casing and holding said well shut in for at least about eight hours to permit the heat from the formation to raise the casing temperature to the normal static formation temperature and thus melt the plug in said passage.

3. A method of completing a well opposite a producing formation comprising circulating for several hours past said formation in said well a liquid at least about 50° F. cooler than the normal static bottom hole temperature of said well, immediately lowering a conduit into said well, said conduit including a section having a passage extending through the wall of said conduit, said passage being plugged by a material having a melting point in the range between the normal static temperature of said formation and a temperature about 20° F. below the normal static temperature of said formation, and holding said well shut in for at least about eight hours to permit the heat from the formation to raise the conduit temperature to the normal static formation temperature and thus melt the plug in said passage.

References Cited in the file of this patent

UNITED STATES PATENTS

2,267,683	Johnston	Dec. 23, 1941
2,772,737	Bond et al.	Dec. 4, 1956
2,775,304	Zandmer	Dec. 25, 1956